

Appendix H4
Evaluation of RESL Biota Sampling

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Appendix H4

Evaluation of RESL Biota Sampling

ABSTRACT

As a consequence of past activities, radionuclides with the potential to adversely affect ecological receptors have been released into the environment at the Idaho National Engineering and Environmental Laboratory (INEEL). Food web modeling was used to calculate the potential exposure of terrestrial ecological receptors to contaminant concentrations in various media for risk assessment purposes. The accuracy of an exposure model depends on the accuracy of the input parameter values and the validity of the model's structure (i.e., the degree to which it represents the actual relationships among parameters at the site). The calibration and evaluation of modeling with site- and contaminant-specific data is critical to adequate risk characterization and interpretation in the risk assessment process. Site-specific field measurements of tissue residue levels (concentrations) are the most reliable means to calibrate model outputs or intermediate calculations. The Environmental Science and Research Foundation was tasked with evaluating the concentrations of radionuclides in terrestrial biota at the INEEL. The Foundation-sponsored studies resulted in a collection of radionuclide tissue concentrations in avian and mammalian receptors. One area that was extensively studied was a group of radioactive leaching ponds. The actual tissue concentration data collected were then compared to the calculated values to evaluate the terrestrial food web modeling used at the INEEL.

ACRONYMS

| | |
|--------|---|
| BW | body weight |
| BDL | below detection limit |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| ED | maximum exposure |
| ERA | ecological risk assessment |
| HR | home range |
| ICPP | Idaho Chemical Processing Plant |
| INEEL | Idaho National Engineering and Environmental Laboratory |
| INTEC | Idaho Nuclear Technology Engineering Center |
| ND | not detected |
| SUF | site use factor |
| TRA | Test Reactor Area |
| WI | water ingestion |

INTRODUCTION

Ecological risk assessment is the process of determining the potential for adverse effects from contaminants on ecological receptor populations and protected wildlife species (individuals and populations). Radionuclide contaminated sites have been identified as part of the CERCLA process at the INEEL. In the absence of radionuclide concentration in receptor tissue, modeling has been conducted to screen sites of concern for ecological receptors. This type of modeling uses conservative assumptions to ensure that the risk assessment results are protective of the receptor.

The INEEL site is typical of cold desert ecosystems and has limited available surface water. Man-made ponds, used to dispose of waste at the INEEL, provide a unique resource to cold desert species. They also provide a habitat for species that would not normally be present in this environment. Exposure modeling of native terrestrial species inhabiting facilities has been limited, because most of the man-made ponds are being remediated and no longer pose concern. It is important to evaluate the exposure modeling that was performed at these sites for adequate risk characterization in the ERA process. Additionally, a better understanding of exposure to terrestrial species in this environment will support the evaluation of new ponds at active facilities and support direction of long-term monitoring of existing ponds at the INEEL.

The Environmental Science and Research Foundation (the Foundation) has conducted numerous radioecological and descriptive ecological studies on the INEEL. Through these efforts, over 50 reports or papers characterizing the extent of contaminant movement have been produced and are considered useful for ERA. Thirty-six of these are useful for describing the nature and extent of contamination in the environment. Those papers used in this report can be found in Attachment 1.

This paper will evaluate the usefulness of using existing data in the reconstruction of exposure to terrestrial species at the INEEL and compare modeled exposure used in the screening risk assessment to actual data collected to identify data gaps, and direct future research.

STUDY AREA

During the late 70s and early 80s the Test Reactor Area (TRA) was extensively studied by Foundation researchers as was the Idaho Chemical Processing Plant (ICPP) now known as the Idaho Nuclear Technology Engineering Center (INTEC).

Terrestrial biota (and other material) sampled at these sites and the dates of the sampling include:

- coyote fecal materials (1978–1979),
- small mammals (primarily deer mice) (1978–1979),
- mourning dove (1974–1977),
- sage grouse (1977–1980),
- barn swallow (1975–1978),
- American kestrel and marsh hawk (1976),
- antelope (1972–1976),

- long-eared owl (1976).

The data used in this evaluation were collected from studies performed at the TRA radioactive leaching ponds and ICPP. At TRA, a complex of three ponds was used for disposal of low-level radioactive wastes from three light-water-moderated and cooled reactors. The first of the three ponds was dug in 1952 (pond 1) and a second pond was dug in 1957 (pond 2). The two ponds constituted a continuous body of water approximately 0.82 ha in area with a mean depth of 3 m. The third pond (0.93 ha) was excavated in 1964 (pond 3). The waste water was pumped into ponds 1 and 2 where it mixed with previously accumulated water and, if necessary, flowed through an overflow flume to pond 3. Pond 3 was nearly filled to capacity (2 m deep) in late 1969 and 1970. A marshy area developed in pond 3 (approximately 0.13 ha). The size of this area fluctuated and was dry during 1970. It has been estimated that approximately 48,880 Ci of beta-gamma activity were released to the ponds from the time of construction to 1978 (EG&G 1979). The leaching ponds were remediated in 1993 and were replaced by lined evaporative ponds. These new ponds are currently being monitored by the Foundation. The ICPP was used to dissolve and recover uranium from spent nuclear fuel and solidify the resultant liquid waste. Trace amounts of radionuclides are atmospherically released as a result of these operations.

METHOD

Foundation studies at the TRA radioactive leaching ponds and ICPP were evaluated for applicability to this process. From this preliminary evaluation, only Cs-137, Pu-238 and Pu-239/240 were adequately sampled. Data presented from both abiotic and biotic media were used to perform the evaluation. The Foundation abstracts are attached to this report, as are summarized tissue concentration data.

The exposure models used in the screening ERAs were used to calculate tissue concentrations for the measured terrestrial species from existing abiotic media concentrations. These calculated concentrations was compared to actual data collected by the Foundation.

TISSUE CONCENTRATION FROM SOIL EXPOSURE

For screening purposes, tissue concentrations from exposure to soil were simplistically calculated by assuming that the steady-state whole body concentration is equivalent to the steady-state concentration of radionuclides in reproductive organs using the equation:

$$TCS = CS \times CF \times ED \times SUF$$

where:

TCS = tissue radionuclide concentration from exposure to contaminated soil (pCi/g)

ED = exposure duration (fraction of year spent in affected area)(unitless)

CS = concentration of the radionuclide in the soil (pCi/g)

CF = concentration factor (unitless)

SUF = site area divided by home range up to 1 (unitless).

WATER INGESTION

Tissue concentration from water ingestion of radionuclides was calculated using a different approach. The simple differential equation:

$$dTCW/dt = I - RDC(TC) - BLC(TC)$$

where:

TCW = tissue concentration from water ingestion

TC = tissue concentration (pCi/g tissue)

I = intake [(pCi/L) (L/g tissue-day)]

RDC = radiological decay constant (1/day)

BLC = biological loss constant (1/day).

Therefore:

$$TCW = I / (RDC + BLC)$$

The daily ingestion rate of the radionuclide from water, I, is calculated:

$$I = (CW * WI) / (BW * 1,000 \text{ g/kg})$$

where:

CW = concentration of the radionuclide in water (pCi/L)

WI = water ingestion rate (L/d)

BW = body weight (kg).

So the tissue concentration due to water ingestion in terrestrial species:

$$TCW = (CW * WI) / (BW * (RDC + BLC) * 1,000 \text{ g/kg})$$

Total Tissue Concentration

$$TCT = TCS + TCW$$

SPECIES PARAMETER INPUT VALUES

Species parameters used for screening to model intakes (tissue concentrations) for the species of interest are presented below. These values are derived from the various key species in the functional groups to which these species belong (see Hampton et al., 1998). The parameters are the maximum exposure duration (ED) and the minimum water ingestion rate (WI) to body weight (BW) ratio and home range (HR).

Table 1. Species Parameter Input Values^a used for TRA.

| Parameter | Deer Mouse | Least Chipmunks | Ord's Kangaroo Rat | Sage Grouse | Barn Swallow | Mourning Dove | American Kestrel | Marsh Hawk | Nuttall's Cottontail ^b |
|---------------------------------|------------|-----------------|--------------------|-------------|--------------|---------------|------------------|------------|-----------------------------------|
| ED (unitless) | 1 | 1 | 1 | 1 | 0.65 | 1 | 1 | 1 | 1 |
| BW (kg) | 0.017 | 0.017 | 0.002 | 0.013 | 0.01 | 0.013 | 0.04 | 0.043 | 0 |
| WI (L/day) | 0.0025 | 0.0025 | 0.002 | 0.0026 | 0.0027 | 0.0026 | 0.01 | 0.0071 | 0 |
| HR (ha) | 0.72 | 0.72 | 0.3 | 5.2 | 8.4 | 5.2 | 9 | 9 | 0.3 |
| SUF (site area/HR) ^c | 1 | 1 | 1 | 0.34 | 0.21 | 0.34 | 0.19 | 0.19 | 1 |

a. All values are for the functional group, which represent the smallest species within that group.

b. Used to assess coyote fecal results.

c. Assuming a site size of 1.75 ha (total size of ponds 1, 2, and 3).

Table 2. Species Parameter Input Values^a used for ICPP.

| Parameter | Sage Grouse | Antelope | Mourning Dove | American Kestrel | Long-eared owl |
|--------------------|-------------|----------|---------------|------------------|----------------|
| ED (unitless) | 1 | 1 | 1 | 1 | 0.65 |
| BW (kg) | 0.013 | 58.5 | 0.013 | 0.04 | 0.279 |
| WI (L/day) | 0.0026 | 3.855 | 0.0026 | 0.01 | 0.025 |
| HR (ha) | 5.2 | 1020 | 5.2 | 9 | 1 |
| SUF (site area/HR) | 0.34 | 0.002 | 0.34 | 0.19 | 1.75 |

a. All values are for the functional group, which represent the smallest species within that group.

b. Assuming a site size of 1.75 ha.

Table 3. Radionuclide Input Values used for TRA.

| Parameter | Cs-137 | Pu-238 | Pu-239/240 |
|---|----------|----------|------------|
| CF ^a | 8.00E-01 | 4.50E-04 | 4.50E-04 |
| RBC ^b | 6.31E-05 | 2.16E-05 | 7.78E-08 |
| BLC ^b | 1.90E-03 | 3.80E-04 | 3.80E-04 |
| Average concentration in water ^c | 2.8 | 0.008 | 0.0076 |
| Maximum concentration in water | 2.8 | 0.016 | 0.015 |
| Sediment (mean) | 22000 | 94 | 108 |
| Average concentration in soil ^d | 110 | 26.1 | 23.5 |
| Maximum concentration in soil ^e | 220 | 0 | 0 |

a. Concentration factors are from IAEA (1994) for Cs-137 and EPA (1989) for plutonium.

b. RBC and BLC from Whicker and Schultz (1982).

c. Cs-137 from (Millard et al., 1978), Pu-238, 239/240 (highest average reported from pond 1 and 2, maximum was estimated from the mean + 2SD) from Ibrahim and Culp (1989).

d. Used range of Cs-137 soil concentrations reported as unpublished data from RESL, 1971 to 1990 (VanHorn et al., 1996). The average was calculated by taking the medium of the values observed (0 to 220 pCi/g). Pu-238 and Pu-239/240 values are as reported in Halford (1987). No range or SD was reported.

Table 4. Radionuclide Input Values used for ICPP.

| Parameter | Cs-137 | Pu-238 | Pu-239/240 |
|---|----------|----------|------------|
| CF ^a | 8.00E-01 | 4.50E-04 | 4.50E-04 |
| RBC ^b | 6.31E-05 | 2.16E-05 | 7.78E-08 |
| BLC ^b | 1.90E-03 | 3.80E-04 | 3.80E-04 |
| Average concentration in water ^c | 0.115 | 0.381 | 0.018 |
| Maximum concentration in water | 0.360 | 1.365 | 0.076 |
| Sediment (mean) | 57.3 | 8.48 | 0.39 |
| Average concentration in soil ^d | 6.24 | 0.021 | 0.018 |
| Maximum concentration in soil ^e | 199 | 0.387 | 0.073 |

a. Concentration factors are from IAEA (1994) for Cs-137 and EPA (1989) for plutonium.

b. RBC and BLC from Schultz and Whicker (1982).

c. Values for water concentrations were calculated using sediment concentrations from sampling done at the percolation ponds on 7/7/94.

d. Used range of Cs-137 soil concentrations reported as unpublished data from RESL, 1971 to 1990 (VanHorn et al. 1996).

Table 5. TRA tissue concentrations as determined by sampling compared to calculated tissue concentrations (pCi/g).

| | Sampled | | | Calculated TCT | | | Calculated TCS | | | Calculated TCW | | |
|---|---------|--------|------------|----------------|--------|------------|----------------|--------|------------|----------------|--------|------------|
| | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 |
| <i>Small mammals (primarily deer mouse)^{a,b}</i> | | | | | | | | | | | | |
| Mean | 112 | 0.016 | 0.014 | 88.21 | 0.0147 | 0.0135 | 88.00 | 0.0117 | 0.0106 | 0.21 | 0.0029 | 0.0029 |
| Maximum | 270 | 0.066 | 0.054 | 176.21 | 0.0059 | 0.0058 | 176.00 | — | — | 0.21 | 0.0059 | 0.0058 |
| Least chipmunk | | | | | | | | | | | | |
| Mean | 11 | 0 | 0 | 88.21 | 0.0147 | 0.0135 | 88.00 | 0.0117 | 0.0106 | 0.21 | 0.0029 | 0.0029 |
| Maximum | 36 | 0 | 0 | 176.21 | 0.0059 | 0.0058 | 176.00 | — | — | 0.21 | 0.0059 | 0.0058 |
| <i>Ord's kangaroo rat</i> | | | | | | | | | | | | |
| Mean | 7 | 0 | 0 | 90.14 | 0.0416 | 0.0406 | 88.00 | 0.0117 | 0.0106 | 2.14 | 0.0299 | 0.0300 |
| Maximum | 38 | 0 | 0 | 178.14 | 0.0598 | 0.0592 | 176.00 | — | — | 2.14 | 0.0598 | 0.0592 |
| Sage grouse | | | | | | | | | | | | |
| Mean | 1.8 | 0 | 0 | 30.21 | 0.0080 | 0.0076 | 29.92 | 0.0040 | 0.0036 | 0.29 | 0.0040 | 0.0040 |
| Maximum | 30.1 | 0 | 0 | 60.13 | 0.0080 | 0.0079 | 59.84 | — | — | 0.29 | 0.0080 | 0.0079 |
| <i>American kestrel</i> | | | | | | | | | | | | |
| Mean | 15 | 0 | 0 | 16.96 | 0.0055 | 0.0053 | 16.72 | 0.0022 | 0.0020 | 0.24 | 0.0033 | 0.0033 |
| (average of four values from four birds) | | | | | | | | | | | | |
| Maximum | 44 | 0 | 0 | 33.68 | 0.0066 | 0.0065 | 33.44 | 0.0000 | 0.0000 | 0.24 | 0.0066 | 0.0065 |
| <i>Marsh hawk</i> | | | | | | | | | | | | |
| Mean (4 values, 2 birds) | 31 | 0 | 0 | 16.96 | 0.0055 | 0.0053 | 16.72 | 0.0022 | 0.0020 | 0.24 | 0.0033 | 0.0033 |
| Maximum | 87 | 0 | 0 | 33.68 | 0.0066 | 0.0065 | 33.44 | 0.0000 | 0.0000 | 0.24 | 0.0066 | 0.0065 |
| <i>Coyote fecal samples^d</i> | | | | | | | | | | | | |
| Mean | 19.9 | 0.015 | 0.03 | 90.14 | 0.0416 | 0.0406 | 88.00 | 0.0117 | 0.0106 | 2.14 | 0.0299 | 0.0300 |
| Maximum | 118 | 0.039 | 0.11 | 178.14 | 0.0598 | 0.0592 | 176.00 | 0.0000 | 0.0000 | 2.14 | 0.0598 | 0.0592 |

Table 5. (continued).

| | | Sampled | | Calculated TCT | | | Calculated TCS | | | Calculated TCW | | |
|------------------------------------|--------|---------|------------|----------------|--------|------------|----------------|--------|------------|----------------|--------|------------|
| | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 |
| <i>Barn swallows^{b,e}</i> | | | | | | | | | | | | |
| Mean | 172 | 0 | 0 | 12.30 | 0.0056 | 0.0054 | 12.01 | 0.0016 | 0.0014 | 0.29 | 0.0040 | 0.0040 |
| Maximum | 254 | 0 | 0 | 24.31 | 0.0080 | 0.0079 | 24.02 | 0.0000 | 0.0000 | 0.29 | 0.0080 | 0.0079 |
| <i>Mourning doves^f</i> | | | | | | | | | | | | |
| Mean | 75.8 | 0 | 0 | 30.21 | 0.0080 | 0.0076 | 29.92 | 0.0040 | 0.0036 | 0.29 | 0.0040 | 0.0040 |
| Maximum | 430 | 0 | 0 | 60.13 | 0.0080 | 0.0079 | 59.84 | 0.0000 | 0.0000 | 0.29 | 0.0080 | 0.0079 |

a. Deer mouse tissue concentration for Cs-137 from Arthur and Markham (1982), other values for small mammals and deer mice are from Halford (1987).

b. Used the maximum = mean + 2SD.

c. Assumed that Cs-137 was the primary contributor to tissue concentration as stated (Craig et al., 1979).

d. Coyote fecal samples were assessed as rabbit.

e. Used the highest maximum and mean from all age groups.

f. Used the highest maximum and mean from all years.

Table 6. ICPP tissue concentrations as determined by sampling compared to calculated tissue concentrations (pCi/g).

| | Sampled | | | Calculated TCT | | | Calculated TCS | | | Calculated TCW | | |
|--|---------|--------|------------|----------------|--------|------------|----------------|-----------|------------|----------------|--------|------------|
| | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 | Cs-137 | Pu-238 | Pu-239/240 |
| <i>Antelope</i> | | | | | | | | | | | | |
| Mean | 0.384 | 0 | 0 | 0.503 | 0.0625 | 0.0448 | 0.499 | 9.45*10-6 | 8.1*10-6 | 0.00386 | 0.0625 | 0.0448 |
| Maximum | 1.5 | 0 | 0 | 15.93 | 0.339 | 0.189 | 15.92 | 1.74*10-4 | 3.29*10-5 | 0.0121 | 0.339 | 0.189 |
| <i>Mourning dove</i> | | | | | | | | | | | | |
| Mean | 2.96 | 0 | 0 | 0.182 | 0.189 | 0.00947 | 0.170 | 3.21*10-6 | 2.75*10-6 | 0.0117 | 0.189 | 0.00947 |
| Maximum | 3.6 | 0 | 0 | 5.45 | 0.68 | 0.04 | 5.413 | 5.92*10-5 | 1.12*10-5 | 0.0367 | 0.68 | 0.04 |
| <i>Sage grouse</i> | | | | | | | | | | | | |
| Mean | 1.8 | 0 | 0 | 0.511 | 0.190 | 0.00947 | 0.499 | 9.45*10-6 | 8.1*10-6 | 0.0117 | 0.190 | 0.00947 |
| Maximum | 30.1 | 0 | 0 | 15.96 | 0.680 | 0.04 | 15.92 | 1.74*10-4 | 3.29*10-5 | 0.0367 | 0.679 | 0.04 |
| <i>American kestrel^a</i> | | | | | | | | | | | | |
| Mean | 0.525 | 0 | 0 | 0.110 | 0.237 | 0.0118 | 0.095 | 1.80*10-6 | 1.54*10-6 | 0.0146 | 0.237 | 0.0118 |
| (average of four values from four birds) | | | | | | | | | | | | |
| Maximum | 0.8 | 0 | 0 | 3.071 | 0.850 | 0.0500 | 3.025 | 3.31*10-5 | 6.25*10-6 | 0.0458 | 0.850 | 0.05 |
| <i>Long eared owl^a</i> | | | | | | | | | | | | |
| Mean (4 values, 2 birds) | 0.12 | 0 | 0 | 0.329 | 0.0850 | 0.00424 | 0.324 | 6.14*10-6 | 5.27*10-6 | 0.00525 | 0.085 | 0.00424 |
| Maximum | 0.40 | 0 | 0 | 10.364 | 0.305 | 0.0179 | 10.348 | 1.13*10-4 | 2.14*10-5 | 0.0164 | 0.305 | 0.0179 |

a. Assumed that Cs-137 was the primary contributor to tissue concentration as stated (Craig et al., 1979).

Tissue concentration estimates were corrected for the size of the site by a site use factor (SUF). The SUF is the site area (ha) divided by the species' home range (ha) constrained to a maximum of 1.

ED is based on the migratory pattern of the receptors. This is determined using the status and abundance data compiled for INEEL species (VanHorn et al. 1995). Water intake rates (L/day) for species of interest were estimated using allometric equations (Nagy 1987). Body weights are from DOE-ID (1999).

LIMITATIONS

No radionuclide decay between studies was incorporated into the assessment. However, studies were selected from similar years since no raw data are available and some data had been decayed for the study. Decay of the Pu-238 and Pu-239/240 likely makes little difference due to their long half-lives. Only a 10 to 20% difference was estimated if Cs-137 was decayed in this timeframe.

Most of the data was taken from published reports. Raw data are not generally available. Published summaries often lack the appropriate information to support this type of evaluation. Additionally, all data was collected for research purposes and does not meet EPA data criteria for risk assessment calculations.

It was assumed that all radionuclides sampled for were reported. In other words all non-detects were reported. This may or may not be the case and is a major data gap in this evaluation. Media (soil) data is especially limited from the timeframe evaluated in this paper. Halford (1987) discussed the variability in soil concentrations. He states that soil samples taken on TRA pond 3 showed considerable variability between successive years (1976 to 1977). Transuranic soil samples taken in 1977 were 0.2 to 9 times those taken in the same locations in 1976. These raw data are not available. The verification of the exposure modeling was compared using this extremely limited data set and the results should be interpreted with care.

CONCLUSIONS

The efforts undertaken by the Foundation to assess the pond at TRA for specific receptors and radionuclides provided information to decision makers at the time of the studies and supported final remediation of these radioactive leaching ponds at TRA. However, receptors and contaminants were focused on human exposure scenarios and did not support a consistent evaluation of exposure to ecological receptors. Selection of receptors was focused on game species which may or may not represent the largest exposure. When interpreting the results it is important to remember that data used have other limitations as discussed in the limitations sections (in some instances these limitations are significant).

The results of this preliminary evaluation indicate that the exposure models used for screening ERA may not be adequately conservative for TRA. Sampled tissue concentrations of Cs-137, Pu-238, and Pu-239/240 in both the deer mouse and mourning dove were greater than calculated tissue concentrations at TRA. The deer mouse is a mammalian omnivore and the mourning dove is an avian herbivore. Calculated tissue concentrations for the marsh hawk and American kestrel are very close to the sampled concentrations at TRA. The exposure models used for screening ERA may not be conservative enough either at ICPP. Sample tissue concentrations of Cs-137 in mourning doves, sage grouse, and American kestrels were greater than calculated tissue concentrations. This study has high uncertainty and limited samples. Overall, the models appear to fairly accurately predict the concentrations in the biota and it may be important to consider this in a screening. Currently, the exposure models are being evaluated and this information will be used to refine these models for future

assessments. This evaluation will also be useful to help direct future characterization and long-term monitoring sampling.

The new ponds at TRA are currently being evaluated by the Foundation and this preliminary evaluation should provide information at direct future studies. INTEC is also currently installing new percolation ponds. Studies should be directed to provide new information on these pond systems containing radionuclides, fill gaps in knowledge, and support decision making concerning the new TRA and INTEC pond complexes and other similar effluent ponds.

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Attachment 1
Article Abstracts Used in the Study

Attachment 1

Article Abstracts Used in the Study

RADIONUCLIDE CONCENTRATIONS IN NESTLING RAPTORS NEAR NUCLEAR FACILITIES (CRAIG ET AL., 1979)

ABSTRACT

The presence of some pollutants in raptors and the importance of raptors as indicators of environmental contaminants have been documented (Olendorff 1973). Literature on radionuclide concentrations in birds near nuclear facilities deals mainly with passerine species (Willard 1960) or waterfowl (Brisbin et al. 1974). The only available literature on raptors concerns radioiodine in thyroids (Hanson and Kornberg 1956). We conducted a study to determine the level of contamination by gamma-emitting radionuclides in nestling raptors near 2 nuclear facilities at the Idaho National Engineering Laboratory Site.

Table A1-1. Radionuclide concentrations in american kestrels and marsh hawk in relation to distance from waste disposal ponds. (from Craig et al., 1979)

| Species | Distance from Facility (km) | Total Activity pCi/g | | Radionuclides Detected (concentrations of individual radionuclides were not provided) |
|------------------------------------|-----------------------------|----------------------|--------|---|
| | | Bird 1 | Bird 2 | |
| Marsh hawk (1 st count) | 0.1 | 1.3 | 1.5 | Se-75, Cs-137, Cs-134, Ni-95, I-131, Co-60, Zn-65, Ba-140, La-140 |
| Marsh hawk (2 nd count) | 0.1 | 35.0 | 87.0 | Se-75, Cs-137, Cs-134, Ni-95, I-131, Co-60, Zn-65, Ba-140, La-140 |
| American kestrel | 0.1 | 44.0 | 11.0 | Se-75, Cs-137, Cs-134, Ni-95, I-131, Co-60, Zn-65, Ba-140, La-140 |
| American kestrel | 0.2 | 1.3 | 3.3 | Cs-137 (three radionuclides were detected but not listed in paper) |

MOVEMENTS AND RADIONUCLIDE CONCENTRATIONS OF SAGE GROUSE IN SOUTHEASTERN IDAHO (CONNELLY AND MARKHAM, 1983)

ABSTRACT

Movements and radionuclide concentrations of sage grouse (*Centrocercus urophasianus*) summering near nuclear facilities on the Idaho National Engineering Laboratory in southeastern Idaho were studied from 1977 through 1980. From 10 July through 7 September, 95% of all locations (N = 131) of radiomarked grouse were within 2 km of their feeding areas on lawns surrounding the facilities. During October and November, 82% of all radiolocations (N = 22) were greater than 2 km from these areas. The maximum one-way movement to winter range was 81 km. Radionuclide concentrations (primarily radiocesium) were higher ($P = 0.05$) in sage grouse summering near a facility with liquid radioactive waste storage than in grouse summering near a solid radioactive waste disposal area or in control areas. The short biological half-life of the ingested radionuclides and the timing of sage grouse movements from summering areas reduced any potential radiation dose to a person consuming one of these birds.

Table A1-2. Frequency of occurrence (%) and maximum and mean^a radionuclide concentrations (pCi/g fresh weight) in tissue samples from sage grouse collected during summer and fall 1977–79 at the Test Reactor Area/Idaho Chemical Processing Plant (TRA/ICPP) complex and control areas. (from Connelly and Markham, 1983)

| Nuclide | TRA/ICPP | | | | | | Control Areas | | | | | |
|---------|-------------------------|-------|------|--------------------|------------------|------|-------------------------|-----|------|--------------------|-----|------|
| | G. I. Tract (N = 29) | | | Muscle (N = 29) | | | G. I. Tract (N = 19) | | | Muscle (N = 20) | | |
| | Freq | Max | Mean | Freq | Max | Mean | Freq | Max | Mean | Freq | Max | Mean |
| Cr-51 | 38 | 539.0 | 60.3 | — | b | — | — | b | — | — | b | — |
| Cs-137 | 93 | 107.0 | 6.2 | 86 | 30.1 | 1.8 | 89 | 0.2 | 0.1 | 90 | 0.4 | 0.3 |
| Co-60 | 31 | 25.2 | 2.0 | 24 | 1.9 | — | — | — | — | — | b | — |
| Ce-144 | 7 | 7.1 | — | — | b | — | 5 | 1.5 | — | — | b | — |
| Cs-134 | 28 | 26.8 | 1.3 | 14 | 5.8 | — | — | b | — | — | b | — |
| Nb-95 | 24 | 1.8 | — | 3 | 0.2 | — | 16 | 0.7 | — | — | b | — |
| Zr-95 | 10 | 1.1 | — | — | — | — | 11 | 0.7 | — | — | b | — |
| Ce-141 | 3 | 2.2 | — | — | — | — | 11 | 0.8 | — | — | 0.3 | — |
| Ru-103 | 7 | 0.9 | — | 3 | 0.4 | — | 11 | 0.6 | — | 5 | b | — |
| La-140 | 7 | 0.6 | — | — | b | — | — | b | — | — | ND | — |
| Se-75 | 17 | 4.5 | — | 3 | 1.4 | — | — | ND | — | — | ND | — |
| Na-24 | — | ND | — | 3 | 3.8 ^c | — | — | ND | — | — | 1.5 | — |
| Ru-106 | — | ND | — | — | ND | — | — | ND | — | 11 | — | — |
| Co-58 | 3 | 0.1 | — | — | ND | — | — | — | — | — | — | — |
| Hg-203 | 7 | 0.6 | — | 7 | 0.5 | — | — | — | — | — | — | — |
| Ba-140 | — | ND | — | 3 | 2.7 | — | — | — | — | — | — | — |
| Mn-54 | 14 | 0.7 | — | 3 | 0.3 | — | — | — | — | — | — | — |
| Zn-65 | 34 | 12.7 | 0.9 | 7 | 1.5 | — | — | — | — | — | — | — |

DENSITY, MOVEMENT, AND TRANSURANIC TISSUE INVENTORY OF SMALL MAMMALS AT A LIQUID RADIOACTIVE WASTE DISPOSAL AREA (HALFORD, 1987)

ABSTRACT

Linear movement, density, and transuranic radionuclide inventory were estimated for small mammals residing at a liquid radioactive waste disposal area in southeastern Idaho. Deer mice (*Peromyscus maniculatus*), kangaroo rats (*Dipodomys ordii*), western harvest mice (*Reithrodontomys megalotis*), and Great Basin pocket mice (*Perognathus parvus*) were the predominant species. The total small mammal population within the 3.0-ha waste area was estimated to be 93. The distance between consecutive captures for all species combined averaged 41 m and ranged from 7 to 201 m. Above 30% of the rodents captured inside the waste area were also captured outside its boundaries. The total population inventory of Pu-238, Pu-239/240, Am-241, Cm-242, and Cm-244 was 44 pCi, 30 pCi, 19 pCi, 21pCi, and <1 pCi, respectively. One-third, or about 35 pCi of transuranics, could be removed from the waste area by small mammals during the summer of 1981.

Table A1-3. Average (Mean +/- SD) and Range of Transuranic Concentrations (pCi/g Dry) in Small Mammal Tissues.* (from Halford, 1987)

| | Pu-238 | Pu-239/240 | Am-241 | Cm-244 | Cm-242 |
|----------------------------|-----------------|-----------------|-----------------|-----------------|-------------------|
| <i>Carcass (internal)</i> | | | | | |
| Mean +/- SD | | | | | |
| (n = 43) | 0.016 +/- 0.025 | 0.014 +/- 0.020 | 0.010 +/- 0.013 | 0.010 +/- 0.015 | 0.0009 +/- 0.0112 |
| Range | BDL † to 0.143 | BDL to 0.100 | BDL to 0.043 | BDL to 0.063 | BDL to 0.060 |
| <i>Gut-Hide (external)</i> | | | | | |
| Mean +/- SD | | | | | |
| (n = 43) | 0.250 +/- 0.780 | 0.163 +/- 0.363 | 0.109 +/- 0.258 | 0.127 +/- 0.302 | 0.003 +/- 0.008 |
| Range | BDL to 5.90 | BDL to 2.26 | BDL to 1.63 | BDL to 1.84 | BDL to 0.03 |

* From the Test Reactor Area radioactive leaching ponds.
† BDL = Below Detection Limit.
SD = Standard deviation

Table A1-4. Average (Mean +/- SD) Transuranic Inventory Per Animal (pCi/Animal) and Total Inventory (pCi) in Small Mammal Population.* (from Halford, 1987)

| | Pu-238 | Pu-239/240 | Am-241 | Cm-244 | Cm-242 |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| <i>Internal</i> | | | | | |
| (n = 43) | 0.043 +/- 0.075 | 0.041 +/- 0.066 | 0.025 +/- 0.039 | 0.025 +/- 0.039 | 0.002 +/- 0.075 |
| <i>External</i> | | | | | |
| (n = 43) | 0.421 +/- 1.215 | 0.281 +/- 0.615 | 0.181 +/- 0.417 | 0.202 +/- 0.460 | 0.007 +/- 0.017 |
| <i>Total/Animal</i> | | | | | |
| (n = 43) | 0.466 +/- 1.248 | 0.321 +/- 0.650 | 0.207 +/- 0.456 | 0.227 +/- 0.499 | 0.009 +/- 0.042 |
| <i>Population Inventory</i> | | | | | |
| (n = 93) | 44 +/- 116 | 30 +/- 60 | 19 +/- 42 | 21 +/- 46 | <1 +/- 4 |

* From the Test Reactor Area radioactive leaching ponds.

RADIONUCLIDE EXPORT AND ELIMINATION BY COYOTES AT TWO RADIOACTIVE WASTE DISPOSAL AREAS IN SOUTHEASTERN IDAHO (ARTHUR AND MARKHAM, 1982)

ABSTRACT

Coyote fecal samples were collected near a radioactive waste leaching pond and a solid radioactive waste disposal facility and analyzed for radioactivity. Elevated concentrations of Cs-137, Sr-90, and Pu-238 in the samples from the liquid radioactive waste leaching area were attributed to coyotes ingesting contaminated pond water and/or small mammals. Assumptions relative to the coyote use of these areas permitted an estimate of the maximum quantity of radioactivity exported and eliminated around the facilities. An annual total of 7.2, 31.4, and 1.8 μCi (Sr-90, Cs-137, Pu-238, Pu-239/240, Am-241, Cm-242, and Cm-244) was eliminated by coyotes within a 6.3 km radius of the solid radioactive waste disposal facility, liquid waste leaching pond, and control area, respectively. These quantities of radioactivity eliminated by coyotes were similar or less than quantities transported by other mechanisms such as waterfowl and vegetative uptake of radioactivity. Coyotes are a mode of radionuclide transport from the two radioactive waste disposal areas; however, due to the low radionuclide concentrations and low yearly radionuclide inventories in coyote fecal samples, it is doubtful that any significant environmental consequences occur as a result of this transport mechanism.

Table A1-5. Radionuclide concentrations in coyote fecal samples collected at the Test Reactor Area (TRA) leaching ponds and control area. (from Arthur and Markham, 1982)

| | | Radionuclide (pCi/g dry weight) | | | | | | |
|---------|----------|---------------------------------|----------------------------|------------------------------|------------------------------|------------------------------|--------------------------------|------------------------------|
| Area | | Sr-90 | Cs-137 | Pu-238 | Pu-239/240 | Am-241 | Cm-242 | Cm-244 |
| TRA | 0 +/- SD | 7.6 _A +/- 7.3* | 19.9 _A +/- 49.2 | 0.015 _A +/- 0.012 | 0.03 _A +/- 0.04 | 0.01 _B +/- 0.01 | 0.0003 _A +/- 0.0007 | 0.008 _A +/- 0.009 |
| | Range | 2.8 – 21.7 | BDL – 271 | BDL – 0.036 | 0.01 – 0.12 | 0.004 – 0.041 | BDL – 0.030 | BDL – 0.026 |
| | N** | 7(7) | 38(34) | 7(5) | 7(7) | 7(7) | 7(1) | 7(5) |
| Control | 0 +/- SD | 0.9 _B +/- 0.2 | 0.7 _B +/- 0.5 | 0.003 _B +/- 0.004 | 0.006 _A +/- 0.003 | 0.003 _C +/- 0.002 | 0.0012 _A +/- 0.0026 | 0.003 _A +/- 0.002 |
| | Range | 0.7 – 1.2 | BDL – 1.8 | BDL – 0.009 | BDL – 0.010 | BDL – 0.005 | BDL – 0.007 | BDL – 0.006 |
| | N | 7(7) | 12(5) | 5(1) | 5(4) | 6(2) | 7(1) | 5(1) |

* Means are followed by the letter A–C. For each radionuclide, means that do not share the same letter are significantly different (P # 0.05).

** First number is sample size; number of samples above detection limit in parenthesis; BDL = below detection limit.

Table A1-6. Concentrations (pCi/g) and frequency of occurrence of fission and activation radionuclides (excluding Sr-90 and Cs-137) in coyote fecal samples from the Test Reactor Area (TRA) leaching ponds and control area. (from Arthur and Markham, 1982)

| | | Radionuclide | | | | | | | | |
|---------|-------|--------------|-----------|-------|-----------|-------|-------------|--------|-------|-------|
| Area | | Cs-134 | Co-60 | Co-57 | Mn-54 | Zn-65 | Ce-144 | Ru-103 | Nb-95 | Zr-95 |
| TRA | Range | 0.6 – 17.0 | 0.6 – 148 | 0.5 | 1.0 – 120 | 3.9 | 11.5 – 35.7 | 1.1 | 11.0 | 9.5 |
| | N* | 38(7) | 38(10) | 38(1) | 38(4) | 38(1) | 38(2) | 38(1) | 38(1) | 38(1) |
| Control | Range | ND | 0.2 | ND | ND | ND | ND | ND | ND | ND |
| | N | 12(0) | 12(1) | 12(0) | 12(0) | 12(0) | 12(0) | 12(0) | 12(0) | 12(0) |

* First number is sample size; number of samples above lower detection limit in parenthesis.

** Not detected.

Table A1-7. Mean^a and maximum whole-body radionuclide concentrations and their contributions to internal dose rates in small mammals captured at the Test Reactor Area radionuclide leaching ponds. (from Arthur and Markham, 1982)

| Radionuclide | Nuclide Concentrations (pCi/g fresh weight) | | | | | |
|--------------------|---|---------|-------------------------------------|---------|-----------------------------------|---------|
| | <i>Peromyscus maniculatus</i> (n = 13) | | <i>Eutamias minimus</i> (n = 13) | | <i>Dipodomys ordii</i> (n = 9) | |
| | Mean | Maximum | Mean | Maximum | Mean | Maximum |
| Cr-51 | 157 | 690 | 29 | 134 | 2 | 11 |
| Cs-137 | 112 | 270 | 11 | 36 | 7 | 38 |
| Co-60 | 36 | 313 | 5 | 20 | 4 | 13 |
| Zn-65 | 29 | 73 | 1 | 4 | <1 | 5 |
| I-131 | 12 | 38 | 20 | 72 | <1 | 5 |
| Se-75 ^b | 12 | 25 | <1 | 2 | <1 | 2 |
| Cs-134 | 11 | 30 | 1 | 3 | 1 | 14 |
| Ce-141 | 4 | 37 | <1 | 2 | ND ^c | — |
| Ce-144 | 4 | 26 | <1 | 3 | ND | — |
| Nb-95 | 2 | 15 | 1 | 2 | ND | — |
| La-140 | 2 | 17 | 1 | 4 | <1 | 1 |

a. Zero used in mean for sample when nuclide not detected.

b. Water concentrations of Se-75 are too low for detection by the analytical procedures used. Therefore, it is not found in the waste data presented in White (1977b).

c. ND = not detected.

RADIONUCLIDE UPTAKE AND GROWTH OF BARN SWALLOWS NESTING BY RADIOACTIVE LEACHING PONDS (MILLARD ET AL., 1990)

ABSTRACT

Populations of barn swallows (*Hirundo rustica*) nested seasonally near the Test Reactor Area (TRA) radioactive leaching ponds on the Idaho National Engineering Laboratory (INEL). These birds utilized leaching pond arthropods as a food source and contaminated mud for nest construction and thus accumulated radioactive materials. Over 20 fission and activation products were detected in immature and adult TRA birds. The radionuclide exhibiting the highest mean concentration in adult birds was ^{51}Cr , with 16.1 Bq g^{-1} (435 pCi g^{-1}). Mean concentrations of detectable radionuclides were used to calculate internal dose rates. Approximately 72% of the total dose rate of $219 \text{ microGy d}^{-1}$ (22 mrad d^{-1}) for adult birds was due to ^{24}Na . Swallow thyroids contained a mean ^{131}I concentration of $3,330 \text{ Bq g}^{-1}$. An average dose rate to the thyroid was calculated to be $4,300 \text{ microGy d}^{-1}$ or 450 mGy (45 rad) for the entire breeding season. Data from LiF-700 thermoluminescent dosimeters in swallow nests indicated that average dose rates were $840 \text{ microGy d}^{-1}$ for eggs and $2,200 \text{ Gy d}^{-1}$ for nestlings, for a total of 54 mGy (5.4 rad) during the nesting period. The breeding biology and growth rate were investigated for TRA swallows and comparison groups located 15 km and 100 km away. Total mortality rates for the comparison group vs. 1976 and 1977 TRA populations were not found to be significantly ($p > 0.9$) different. Nonlinear regression was used to fit individual growth curves and estimate parameters using a logistic model. First clutch TRA swallows were found to have a significantly ($p < 0.0$) lower mean growth rate compared to either the first clutch comparison group or the second clutch of TRA birds. Mean asymptotic weights achieved by immature TRA birds were also found to be significantly ($p < 0.05$) lower than those achieved by comparison group birds. Both growth rate and asymptotic weights for TRA birds were within the normal range reported in the literature. The cause for the statistical difference in growth rate between the comparison group and TRA first clutch populations could not be determined.

Table A1-8. Average radionuclide concentrations and mean whole-body dose rates in barn swallows nesting by the Test Reactor Area Ponds and under a nearby highway bridge.^a (from Millard et al., 1990)

| Nuclide | Concentration (pCi/g whole-body +/- SD) | | | |
|---------|---|-------------------|------------------|---------------|
| | Immatures ^b | TRA Immatures | | TRA Adults |
| | >10 g (n = 6) | 0–10g (n = 34) | >10g (n = 79) | (n = 16) |
| Na-24 | 33.0 +/- 14.9 | 1.23 +/- 15.9 | 171 +/- 33.0 | 233 +/- 47.0 |
| Cr-51 | 57.0 +/- 23.0 | 278 +/- 35.1 | 289 +/- 75.9 | 435 +/- 64.1 |
| Co-60 | 2.43 +/- 0.54 | 34.1 +/- 5.95 | 8.11 +/- 1.08 | 40.0 +/- 5.14 |
| Zn-65 | 21.9 +/- 1.89 | 158 +/- 21.9 | 330 +/- 28.9 | 160 +/- 28.1 |
| Se-75 | 5.95 +/- 1.08 | 30.0 +/- 2.97 | 91.9 +/- 8.11 | 135 +/- 25.9 |
| I-131 | 8.11 +/- 5.14 | 30.0 +/- 5.95 | 98.1 +/- 8.11 | 150 +/- 33.0 |
| Cs-134 | 3.24 +/- 0.81 | 11.1 +/- 1.89 | 18.1 +/- 1.89 | 35.9 +/- 7.03 |
| Cs-137 | 7.03 +/- 1.89 | 38.1 +/- 5.95 | 68.9 +/- 8.11 | 172 +/- 41.1 |
| Ba-140 | 5.95 +/- 1.89 | 28.9 +/- 5.95 | 61.1 +/- 7.03 | 21.9 +/- 5.14 |

a. Whole-body wet weight concentrations were reported for radionuclides with percent occurrences greater than 50%. Lanthanum-140 was not included because this nuclide could not be decay-corrected to sampling date. Concentrations included contributions from feathers and the GI tract and its contents.

b. Immature birds collected from highway bridge 1.5 km from ponds.

Note: Dose rates were calculated for individual swallows assuming the above radionuclide concentrations were uniformly distributed in tissues.

RADIONUCLIDES IN MOURNING DOVES NEAR A NUCLEAR FACILITY COMPLEX IN SOUTHEASTERN IDAHO (MARKHAM AND HALFORD, 1982)

ABSTRACT

The Idaho National Engineering Laboratory Site in southeastern Idaho contains the world's largest concentration of nuclear reactors; to date some 52 reactors have been constructed and 17 reactors are still operable. In addition, the INEL contains a nuclear fuel reprocessing plant, terrestrial areas for the disposal of solid radioactive wastes, and leaching ponds for the disposal of contaminated liquid wastes. With the exception of uranium mining and fuel fabrication, the INEL activities include all the nuclear fuel cycle.

Mourning doves (*Zenaida macroura*) are ubiquitous game birds in Idaho and are common on the INEL during the summer (Reynolds and Trost 1981). They forage, obtain grit and/or drink water at or near these facilities (Trost et al. 1976, Halford and Millard 1978, Arthur and Markham 1978).

The potential exists for mourning doves at these facilities to ingest radionuclides. Since birds are the most mobile of the animals occurring near nuclear facilities and since doves are a popular game species, it is possible that radioactively-contaminated birds could be ingested by and thus provide a radiation dose to man. Other predators, such as raptors, could also ingest radionuclides by consuming doves. The purposes of this study were (1) to determine the concentrations of radionuclides in mourning dove tissues near various types of nuclear facilities, (2) to determine the consequent radiation dose to doves, (3) to determine the consequence of the transfer of radionuclides through the food chain and (4) to relate these concentrations to potential radiation doses to man.

Table A1-9. Cesium-137 concentrations (pCi/g) in muscle tissue from mourning doves using the Test Reactor Area radionuclide leaching ponds. (from Markham and Halford, 1982)

| Year of Collection | Mean | Range | N |
|--------------------|------|----------|----|
| 1974 | 2.12 | >0.4-7.8 | 17 |
| 1975 | 41.1 | <0.6-430 | 16 |
| 1976 | 1.12 | <0.6-1.6 | 5 |
| 1977 | 75.8 | <0.6-419 | 12 |

Table A1-10. Radionuclides other than Cs-137 in mourning dove tissues 1974–1977. (from Markham and Halford, 1982)

| % Occurrence N = 50 | | | | % Occurrence N = 50 | | | |
|------------------------|--------|----------|---------------------------------------|------------------------|--------|----------|---------------------------------------|
| Radionuclide | Muscle | GI Tract | Max. Tissue Concentration pCi/g | Radionuclide | Muscle | GI Tract | Max. Tissue Concentration pCi/g |
| Cs-134 | 24 | 20 | 19 | Co-57 | 0 | 2 | 0 |
| I-131 | 4 | 22 | 1.8 | Co-58 | 0 | 2 | 0 |
| Co-60 | 26 | 34 | 2.2 | Ni-95 | 2 | 6 | 0.2 |
| Cr-51 | 2 | 34 | 139 | Zi-95 | 0 | 8 | 0 |
| La-140 | 0 | 8 | 0 | Se-75 | 4 | 8 | 6.5 |
| Ce-141 | 0 | 4 | 0 | Ce-132 | 2 | 0 | 89.5 |
| Ce-144 | 0 | 6 | 0 | Ha-181 | 0 | 2 | 0 |
| Ru-103 | 0 | 2 | 0 | Zn-65 | 0 | 2 | 0 |
| Ru-106 | 0 | 0 | 0 | Sb-125 | 0 | 2 | 0 |
| Mn-54 | 0 | 2 | 0 | Ba-140 | 0 | 4 | 0 |

**RADIONUCLIDES IN PRONGHORN RESULTING FROM NUCLEAR
FUEL REPROCESSING AND WORLDWIDE FALLOUT
O. D. MARKHAM ET AL. (1982)**

ABSTRACT

During 1972–76, rumen, lung, muscle, and liver tissues from pronghorn (*Antilocapra americana*) collected near the Idaho Chemical Processing Plant (ICPP) on the Idaho National Engineering Laboratory (INEL) Site, on adjacent INEL areas, and on offsite control areas were analyzed for gamma-emitting radionuclides. Although up to 14 radionuclides appeared in pronghorn rumen contents, only ^{137}Cs was consistently detected in muscle and liver samples. Cesium-137 concentrations in pronghorn muscle from near the ICPP averaged 384 pCi/kg, and were higher ($P < 0.01$) than concentrations in other onsite pronghorn (53 pCi/kg) and offsite controls (38 pCi/kg). Concentrations of ^{137}Cs in livers were slightly higher, and lung concentrations were much lower than muscle concentrations. Maximum dose commitment to man consuming the muscle and liver of a pronghorn was 2.7 mrem. Radiation doses to pronghorn from radionuclides reported in this and other studies are discussed in relation to the 3 study areas, and are compared to doses pronghorn receive from naturally occurring radionuclides. Radiation doses to pronghorn and to man eating the pronghorn are below guidelines established for man. Pronghorn appear to be useful bioindicators of radionuclides in the environment.

Table A1-11. Gamma-emitting radionuclides in rumen, muscle, and liver samples from pronghorn collected near the Idaho Chemical Processing Plant and other areas on or near the Idaho National Engineering Laboratory Site, 1972–76. (from O. D. Markham et al. 1982)

| Concentrations (pCi/kg dry) | | | | | | | | | |
|-----------------------------|--------------------|----------|-------------------|--------------------|----------|--------------|--------------------|----------|------|
| ≤ km of ICPP | | | | Remainder of INEL | | | Offsite | | |
| Nuclide | Percent Occurrence | Max. | Avg. ^a | Percent Occurrence | Max. | Avg. | Percent Occurrence | Max. | Avg. |
| <i>Rumen</i> | | | | | | | | | |
| | | (N = 17) | | | (N = 21) | | | (N = 12) | |
| Cs-137 | 94 | 24,000 | 5,680 | 95 | 1,460 | 365 | 92 | 460 | 250 |
| Cs-134 | 47 | 9,100 | 550 | 0 | — | — | 0 | — | — |
| Ru-106 | 53 | 53,000 | 5,880 | 14 | 1,520 | ^b | 0 | — | — |
| Ru-103 | 0 | — | — | 24 | 270 | 85 | 33 | 230 | 90 |
| Ce-144 | 47 | 7,460 | 1,285 | 43 | 6,730 | 1,020 | 33 | 2,000 | 380 |
| Ce-141 | 6 | 970 | ^b | 24 | 995 | 144 | 0 | — | — |
| Zr-95 | 18 | 990 | ^b | 48 | 8,500 | 655 | 50 | 980 | 220 |
| Nb-95 | 35 | 1,800 | 330 | 52 | 11,000 | 895 | 58 | 780 | 290 |
| Sb-125 | 24 | 4,000 | 825 | 14 | 275 | ^b | 0 | — | — |
| La-140 | 6 | 180 | ^b | 19 | 330 | ^b | 0 | — | — |
| Mn-54 | 0 | — | — | 10 | 70 | ^b | 0 | — | — |
| Co-60 | 12 | 430 | ^b | 0 | — | — | 0 | — | — |
| Ba-140 | 6 | 180 | ^b | 0 | — | — | 0 | — | — |
| Eu-154 | 6 | 420 | ^b | 0 | — | — | 0 | — | — |

Table A1-11. (continued).

| Concentrations (pCi/kg dry) | | | | | | | | | |
|-----------------------------|--------------------|-------|-------------------|--------------------|------|--------------|--------------------|------|--------------|
| Nuclide | ≤ km of ICPP | | | Remainder of INEL | | | Offsite | | |
| | Percent Occurrence | Max. | Avg. ^a | Percent Occurrence | Max. | Avg. | Percent Occurrence | Max. | Avg. |
| <i>Muscle</i> | | | | | | | | | |
| | (N = 22) | | | (N = 26) | | | (N = 17) | | |
| Cs-137 | 100 | 1,520 | 384 | 100 | 130 | 53 | 100 | 92 | 38 |
| Cs-134 | 23 | 100 | 22 | 0 | — | — | 0 | — | — |
| Co-60 | 0 | — | — | 8 | 32 | ^b | 18 | 40 | ^b |
| <i>Liver</i> | | | | | | | | | |
| | (N = 19) | | | (N = 19) | | | (N = 15) | | |
| Cs-137 | 95 | 2,660 | 680 | 100 | 146 | 56 | 100 | 139 | 47 |
| Cs-134 | 42 | 150 | 41 | 0 | — | — | 0 | — | — |
| Co-60 | 5 | 30 | ^b | 11 | 60 | ^b | 7 | 23 | ^b |
| Mn-54 | 0 | — | — | 5 | 10 | ^b | 0 | — | — |
| Ru-103 | 0 | — | — | 0 | — | — | 7 | 39 | ^b |
| Zn-65 | 5 | 36 | ^b | 0 | — | — | 0 | — | — |

a. Minimum detection limits were used in calculations when radionuclide was not detected in sample.

b. Averages were not calculated for occurrence below 20%.

**EFFECTS OF DECREASED EFFLUENTS FROM NUCLEAR FUEL
REPROCESSING ON ¹³⁷CS CONCENTRATIONS IN WILDLIFE
O. D. MARKHAM AND D. K. HALFORD (1985)**

ABSTRACT

During 1975, additional fiberglass prefilters and HEPA filters were added to the existing air filtering system for atmospheric effluents from the Idaho Chemical Processing Plant (ICPP) on the Idaho National Engineering Laboratory. Pronghorn (*Antilocapra americana*) muscle and liver samples collected near the ICPP prior to filter installation contained Cesium-137 concentrations that were 13 and 18 times, respectively, the concentrations in tissues of control animals. Muscle and liver samples collected after filter installation had only 2.5 times the ¹³⁷Cs concentrations in control tissues. The potential committed dose equivalent to man consuming the muscle and liver of a pronghorn from the ICPP vicinity was reduced by a factor of 10 by the addition of the filtering system. Although not statistically significant ($P > 0.05$), ¹³⁷Cs concentrations in mourning doves (*Zenaida macroura*) were reduced by a factor of four after the additional effluent filters at ICPP were installed.

Table A1-12. Cesium-137 in edible tissues of pronghorn antelope and mourning doves before and after installation of additional atmospheric effluent filters at the Idaho Chemical Plant (ICPP). (from O. D. Markham and D. K. Halford 1985)

| Date | Sample Size | ICPP Avg. \pm SD | Range | Sample Size | Control Area Avg. \pm SD | Range |
|---|-------------|-----------------------|-----------------------|-------------|-------------------------------|-------------|
| <i>Pronghorn Muscle (pCi/g)</i> | | | | | | |
| 1972- Aug. 1975 | 14 | 0.57 \pm 0.48 | 0.03 – 1.52 | 12 | 0.04 \pm 0.02 | 0.02 – 0.09 |
| Sept. 1975–1976 | 8 | 0.05 \pm 0.04 | 0.05 – 0.14 | 5 | 0.02 \pm 0.01 | 0.01 – 0.03 |
| <i>Pronghorn Liver (pCi/g)</i> | | | | | | |
| 1972– Aug. 1975 | 12 | 1.04 \pm 0.83 | 0.06 \pm 1.77 | 10 | 0.06 \pm 0.04 | 0.02 – 0.14 |
| Sept. 1975–1976 | 7 | 0.07 \pm 0.08 | BDC ^{a-0.20} | 5 | 0.03 \pm 0.01 | 0.02 – 0.04 |
| <i>Mourning Dove Muscle (pCi/g)</i> | | | | | | |
| 1974 | 16 | 3.2 \pm 3.6 | BDC – 11.6 | 16 | <0.4 \pm 0.1 | BDC – 0.8 |
| 1976 | 4 | 2.0 \pm 2.2 | 0.7 – 5.3 | 8 | BDC | BDC |
| a. BDC — Below detectable concentration | | | | | | |

Table A1-13. Annual Cs-137 atmospheric releases from the Idaho Chemical Processing Plant.
(from O. D. Markham and D. K. Halford 1985)

| Year | ¹³⁷ Cs Released (Ci) |
|---------------------------|------------------------------------|
| Before Additional Filters | |
| 1972 | 4.6 |
| 1973 | 5.4 |
| 1974 | 6.7 |
| After Additional Filters | |
| 1975 | 0.6 |
| 1976 | 0.1 |